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Environmental impact assessment in coal-burning power plants based on AHP and entropy weight VIKOR method

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Abstract

In the case of increasing power demand and increasingly serious environmental pollution, the study on environmental impact of coal-fired power plants on coal-fired power generation projects with coal as the main raw material has certain theoretical significance and practical value. Based on the comprehensive impact of coal-fired power plants on the environment, this paper studies the environmental impact assessment index system and assessment methods of coal-fired power plants in Taiwan. Firstly, the paper analyzes the environmental impact of coal-fired power plants. Then the comprehensive evaluation index system, the selection of evaluation factors, the quantification of evaluation indexes and the evaluation model of the environmental impact of coal-fired power plants are emphatically studied. The analytic hierarchy process (AHP) was applied to determine the weight of each index, and then a comprehensive evaluation model was established using VIKOR method. The whole index system was firstly evaluated from three aspects, namely nature, ecology and economic society, and then the overall comprehensive evaluation was carried out. Finally, the index system and model are applied to the actual evaluation of power plants, and the feasibility of the model is illustrated with an example, so as to provide a method reference for the environmental impact evaluation of power plants.

Keywords: coal-burning power plants, environmental impact assessment, Analytic Hierarchy Process (AHP), entropy weight, Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR)

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INTRODUCTION

At present, Taiwan's electric power structure is mainly composed of thermal power generation, and the energy used in its power generation process is mainly coal. In the process of power generation operation, power plants will produce pollutants harmful to the environment, such as waste water and dry ash generated in the process of power generation, toxic gases such as carbon dioxide, sulfur dioxide and inhalable particles discharged into the atmosphere through the chimney, and noise generated by boilers. The storage and transportation of coal burning, ash transportation, main project and the land occupation of transportation project may also cause certain ecological and social impacts. Although many power plants use desulphurization and other equipment, it is difficult to effectively remove the content of pollutants, electrostatic dust removal equipment is difficult to fully absorb existing ultra-fine coal flue gas, ultra-light and easily dispersed dust. Therefore, according to the characteristics of the coal engineering and pollution characteristics, in the process of power plant operation, to reduce the impact on the environment, through the atmosphere, water, soil and other aspects of the investigation, through the study of the detection of environmental quality, beneficial to the improvement of the power plant environmental protection measures and management of various pollutants, environmental impact analysis and evaluation, is beneficial to the optimization of production process, is the urgent need to solve the problem of power plant exist in Taiwan, not only to the construction of green plants, but also is beneficial to the sustainable and healthy development of the plant.

The study of environmental impact assessment of coal-fired power plants, not only can fully explain the actual environmental impact produced by running of power plant, to determine the validity of the existing environmental protection measures, such as the application of desulfurization denitrification equipment, and pointed to offset or eliminate the environmental impact of the power plant, provide impact prediction feedback information to ensure the effectiveness of pre-assessment, can also be evaluated the actual effects of

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environmental protection measures. Learn experience and summarize lessons for future project decision-making, so as to achieve better environmental, economic and social benefits.

LITERATURE REVIEW

To change to the environment pollution make afterward that take temporary solution not effect a permanent cure, when with pollution control, active prevention, control, in case is given priority to, 60 s, Canada and the United States scholars put forward the concept of “environmental impact assessment (EIA)”, the United States (1970), Canada (1973), the European Union (1975), the former Soviet union (1988) and Japan and other developed countries has enacted the EIA law, established the EIA system. China started EIA research and practice only in 1973 (EIA Centre, 1996). American leaders enacted the National Environmental Policy Act in 1970. It is mainly divided into two parts. One is the regulation on national environmental policy, which requires the federal government to carry out projects and activities in accordance with the regulations, and the detailed environmental impact assessment report should be attached; Second, the establishment of the committee on environmental quality. EIA is not only gradually promoted, applied and improved as a system, but also as an effective environmental management tool. Many scholars and experts have carried out theoretical and applied studies on EIA, is as follows: As the founder of Environmental Impact Assessment (EIA), Munn (2002) has established a complete theoretical system of EIA and described the research objectives, steps, essence, essentials and implementation measures of EIA. The concept of EIA is to comprehensively identify and evaluate the potential impact of proposed projects, plans, designs or regulatory operations on the physical and chemical properties, biological species, civilization construction and socio-economic factors of the overall ecological environment (Homagain et al., 2015). The theory of EIA is to elaborate the principles and methods of individual environmental factors such as atmosphere, water, biology, social economy, etc. Some researches gave the content of EIA for waste disposal engineering, which mainly includes project definition, environmental impact analysis, project resolution and implementation, etc. (Hai et al., 2014; Sheng et al., 2014; Menglei and Yenchin, 2015).

Some studies assess the impact of pollutants on the environment and human body in a monetized manner, quantifying the external costs of energy production over production. Coursey and Kim (1997) are trying to find out, meet the incentive compatible (incentive compatibility) with budget constraints and maximization of the total utility of all participating in community optimum compensation to solve the problem of adjacent suspension, and summing up the compensation mechanism of three kinds of optimum: the first is direct compensation mechanism, the government will choose to participate in community first, then put forward by the village respective may affected by the amount of compensation (willingness to accept, WTA); Before proposing the amount of compensation, these communities will know that the one who is willing to receive the lowest amount of compensation will be selected to set up and receive the amount of compensation, while the other communities will divide the amount equally; The advantage of this mechanism is efficiency, and the least cost cell will be selected to set up. The second is the second-low compensation mechanism, which is the same as the direct compensation mechanism in principle. It is hoped that the person with the lowest compensation amount will receive the second lowest amount of compensation: this compensation mechanism is also very efficient and can prevent collusion. The third is the bid-down compensation mechanism, which is the same as the previous two at the beginning. The government chooses to participate in the community, and then the founder decides the maximum amount of compensation. Then, if any community is willing to set up the facility, the compensation will be reduced. After the process lasts until only one community is willing to set up the facility, the community can multiply the compensation amount proposed by the number of other communities and then divide the amount by the number of all other communities, and the other communities will divide the amount equally. The compensation mechanism is efficient, balanced and can prevent collusion.

Groothuis et al. (2008) studied Watauga County, North Carolina and designed a scenario simulation asking if they would like to participate in the Green Energy program to provide greener energy but pay a higher price to get a detailed understanding of which local residents would prefer the benefits of wind power); A final logit Analysis found that the higher percentage of participants were younger, had not lived in the area for generations, and were more in favour of wind power as a clean energy source. In addition, the paper estimates the willingness of each household unit to be compensated by the WTA. Next, bivariate probit analysis found that those who were willing to participate in green energy plan were more willing to support WTA scheme. This result also means that those who are willing to pay higher price to support environmental protection have lower compensation amount.

In other relevant literatures, regarding the location of energy facilities, Raj and Lemoff (2009) to study with base station site selection, analysis of the risk on the basis of risk assessment to consider when setting station social risk and individual risk, and the site of factory facilities must carry out the following risk assessment, first list could potentially lead to the type of

LNG leakage incident, and then assess the location, range, quantity and time of discharge, then evaluate the different types of emission probability, then evaluate the consequences, finally calculated risk and comparing with acceptable risk. Havens and Spicer (2007) studied the potential problems of the regulation for the location of LNG receiving station In the United States, and thought that NIMBY facility and community group communication were part of the regulation, and that BANANA (Build Absolutely Nothing Near Anybody) and NIMBY (Not In My Backyard) were the common problems of the profit group and the non-profit group, and it was necessary to communicate and reach a consensus. Kunreuthur et al. (1984) put forward the decision-making process of dangerous facilities (e.g., nuclear power plant, liquefied natural gas plant, gas station, chemical plant, etc.) in his risk and policy analysis decisions. Risk analysis and policy analysis are two main analytical tools. Although risk analysis is used to estimate the probability of the occurrence of disaster accidents, the estimated results often differ greatly from the actual situation. As the LNG terminal is a dangerous facility, its construction involves legal restrictions, protests from nearby residents, opposition from environmental groups, and authorization from national legislatures. Therefore, there must be a lot of conflicts and coordination, and the decision-making process must be reviewed through risk and decision analysis.

Some scholars have conducted studies on the assessment of environmental impact location criteria. There is a lot of literature on the topic of research and application of AHP based on Saaty (1980, 1986) and Zahedi (1986, 1987, 1988). About location choice of literature including flower industry industrial production location selection, construction material suppliers to location, the thermal power plant site selection, the enterprise in a specific area not enter mode selection, new product development of small and medium-sized enterprises, the critical success factor research, the key factors of outsourcing business model research, adjacent to avoid facility site selection, petrochemical industry, work safety incident prevention factors assessment, etc. Boyle (1998) wrote an article in 1998 that described the basic elements of the environment (1998) and made a systematic overview [6]. Braaf (1999) made a specific analysis and evaluation of the environmental impact system using AHP and combinative weight method. Chang (2003) based on the exemption degree of clean energy, analyzed the environmental impact system.

Some of the above methods are too simple to accurately evaluate the actual situation of environmental impact of coal-fired power plants, and some are too complex to popularize and use. AHP has strong subjectivity and sometimes overstates or reduces the role of some indicators, making the results less objective and accurate. Therefore, it is necessary to further study the optimization method for evaluating the environmental impact of coal-fired power plants. VIKOR method belongs to the optimal compromise solution of multiple attribute decision making method, first determine the ideal solution, then calculate each alternatives and determine its and the ideal solution for the assessment of the value of proximity, calculated the priorities, the method considering the relationship between group and individual benefit maximization regret minimization, thus can choose the comprehensive benefit of the optimal solution (Tzeng and Huang, 2011). Considering the limitation of determining the index weight by a single subjective or objective method, this study firstly used AHP and entropy weight method to comprehensively calculate the weight of each evaluation index, and then made a decision by VIKOR method to comprehensively evaluate the environmental impact of coal-fired power plants.

PROPOSED MODEL

Power Generation Process of Coal-fired Power Plants

The raw material coal used in coal-fired power generation, as a chemical fuel, will eventually be converted into electricity with use. The production process diagram of coal-fired power plant is shown in **Fig. 1**. The first is the transportation of raw materials. Coal is transported from the coal dock to the dry coal shed and then to the coal scuttle. In order to improve the efficiency of coal burning, pulverized coal is mostly burned. Therefore, the coal is first sent to the coal crusher to be broken into pieces, and then sent to be pulverized. Then with the hot air is sent into the boiler furnace combustion. At the same time, the boiler will produce noise. The pulverized coal will eventually enter the dust collector after combustion. After the flue gas from the fume hood is desulphurized by the desulfurization unit, it is discharged into the atmosphere through the chimney under the action of the induced draft fan. After the coal is burned, it reaches the cinder hopper under the ash boiler, enters the plane, and finally becomes an ash farm or takeaway. At the same time, the dry ash separated from the dust catcher also enters the ash field or is used for takeout. In the economizer, the flue gas enters the top of the drum boiler, and the heat released by coal powder combustion is high. After reaching the drum, it is vaporized into steam and connected to the cold wall, and the saturated steam enters the superheater. Saturated steam continues to absorb heat, and when it has a very high temperature and pressure, it is called superheated steam. When the pipe enters the steam turbine, the heat energy is converted into kinetic energy. At this time, the steam turbine operation will produce greater noise. When kinetic energy is transferred to a generator, it is

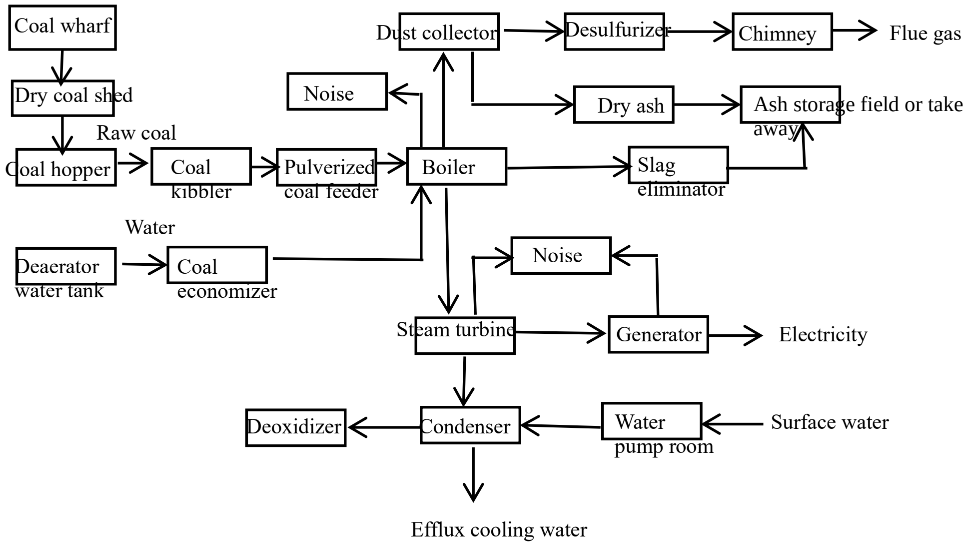

Fig. 1. Power generation process of coal-fired power plants

converted into electrical energy. The generator transmits its telex to the user while it makes a noise.

Pollution-producing Process of Coal-fired Power Plants

According to the traditional technological process of coal-fired power plants, it can be seen from **Fig. 1** that coal storage, transportation, coal combustion and power generation may cause environmental pollution. In general, the main pollutant discharge links can be divided into the following: 1. coal storage and transportation process. 2. The process of fuel storage and transportation: Due to the dehydration of the tank, a small amount of oily sewage may be generated during the storage or transportation of fuel. 3. Combustion process: the combustion process of coal-fired power plants, including the pulverization process of coal burning. In the process of boiler combustion, the flue gas produced by combustion is discharged into the atmosphere through the dust removal and desulfurization device from the chimney. The polluted gas includes carbon oxide, sulfur oxide and nitrogen oxide. Wastewater includes alkaline wastewater, purification wastewater, boiler desulfurization wastewater and boiler cleaning wastewater. 4. Chemical water treatment process: In order to ensure the normal operation of the power plant, it is necessary to provide qualified industrial water for treatment. In the process of treatment, a certain amount of acid and alkali wastewater will be produced. 5. Process of external cooling water drainage: Steam is discharged from the lower part of the exhaust port of the steam turbine and enters the condenser to form cooling water. 6. Power generation process. 7. Ash removal process: In this process, a lot of ash and ash water will be produced. Dust may be generated during loading, transportation and storage if management negligence or adverse weather conditions occur. If the ash flushing water leakage in the ash storage field is caused, the groundwater will be polluted.

The Environmental Impact Assessment Index System of Coal-fired Power Plants

This study combined with the construction of the project area development planning, environmental planning, environmental function districts, ecological function area and environment status quo, on the basis of the characteristics of the construction project, the main characteristics of the environmental impact, according to the regional environmental function requirements, environmental protection goals and environmental constraints, and comprehensively in the literature evaluation standard to filter evaluation index are determined. In this study, based on the selection principles of the above impact indicators and through the analysis of the environmental impact factors of power plants, the four aspects of natural environment, ecological environment, social and economic environment, and the enterprise's own environment are taken as the criteria evaluation indicators of the environmental impact of coal-fired power plants, which are described as follows: 1. The natural environment index of power plant includes: atmospheric environment, water environment, solid waste discharge environment, noise environment and so on. 2. The eco-environmental indicators of power plants include: soil quality type of the region and stability of the ecological environment. The construction of power plant project has two impacts on regional ecology: first, the pollutants destroy the soil structure and lead to land desertification and soil erosion, thus causing the decrease of soil quantity. Second, the construction of power plants will expropriate local land resources and change the form of land use. 3. For the determination of socio-economic environmental

Table 1. The environmental impact assessment index system of coal-fired power plants (Q)

First level index	Second level index	Third level index
Natural environment impact Q_1	Atmospheric environment impact X_1	Sulfur dioxide emission concentration X_{11}
		Nitrogen oxide emission concentration X_{12}
		TSP (Total suspended particulates) concentration X_{13}
	Water environment impact X_2	PH X_{21}
		COD (Chemical Oxygen Demand) X_{22}
		Suspended solids X_{23}
	Noise impact X_3	Noise decibel size X_{31}
Influence of social environment Q_2	Influence on the social and economic development of the neighborhood X_4	
	Influence on the contribution of technology progress X_5	
	Influence of waste (ash comprehensive utilization rate) X_6	
	Proportion of environmental protection investment X_7	
	Influence on the surrounding residents X_8	
Ecosystem stability Q_3	Influence of ecological environment X_9	
	Influence on land resources X_{10}	

Table 2. Comparison of standard meanings

Standard values	Illustration
1	X_i is equally important asX_j
3	X_i is slightly more important than X_j
5	X_i is significantly more important than X_j
7	X_i is strongly important to X_j
9	X_i is absolutely important to X_j
2、4、6、8	are between the above standard values

If X_i and X_j compare to a_{ji}, then X_i and X_l get $1/a_{ij}$

impact assessment indicators, specific data cannot be used for quantitative analysis. Instead, language description can only be used for qualitative analysis based on the pros and cons of its impact degree.

So, two qualitative indicators are selected: one is the impact on local social and economic development; Second, the impact on regional public satisfaction. (1) The impact of social and economic development. As mentioned earlier, the construction and operation of the power plant will give a driving force to the local economic development. But at the same time, environmental damage or resource waste may occur, which requires a comprehensive evaluation of its advantages and disadvantages. (2) The impact on the satisfaction of surrounding residents. The construction of the power plant will inevitably have a certain impact on the residents in the surrounding areas, such as the land expropriation and demolition process, as well as the air pollution generated in the operation process of the power plant, etc., which mainly depends on whether the power plant satisfies the local residents in terms of the land expropriation compensation in the early stage and the feasibility of the project design. Therefore, the environmental impact assessment index system of coal-fired power plants is shown in **Table 1**.

Determination of Weight for the Environmental Impact Assessment Index

Determination of objective weight of indicators

The basic steps to determine the objective weight of indicators by entropy weight method are as follows:

1. Determine the judgment matrix and build the judgment matrix A

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

According to the hierarchical structure model and comparison standard (Satty, 1980) can be obtained (**Table 2**).

2. Calculate the index weight

Calculate the maximum eigenvalue of judgment matrix and, and then its corresponding feature vector *W*, namely

$$AW = \lambda_{max} W \quad (1)$$

The square root method is used for calculation. We are going to multiply each element of the rows of A, and then we are going to take the 1/n to get the vector *T*, and normalize *T* to get *W*.

$$t_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \quad (2)$$

$$\omega_i = t_i / \sum_{i=1}^{n} t_i \quad (3)$$

Calculate the maximum eigenvalue of *A*:

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{n\omega_i} \quad (4)$$

Where *i* = 1, 2, …, *n*; j = 1, 2, …, n.

3. Calculate the consistency index

The consistency test formula for calculating the judgment matrix of the consistency index is *CR* = *CI* /*RI*. Where, *CI* is the consistency test indicator, $CI = (\lambda_{max} - n) / (n - 1)$; n is the order of *A*; *RI* is the average random consistency index, and its values are shown in **Table 3**. When *CR* < 0.1, the consistency test is satisfied. At this

Table 3. The average random consistency index

order	3	4	5	6	7	8	9
RI	0.52	0.89	1.12	1.26	1.36	1.41	1.46

time, the calculated eigenvector *W* is the weight of each index; otherwise, the matrix *A* needs to be rebuilt.

Determination of subjective weight of indicators by entropy method

The entropy weight method, also known as the information entropy method, is an objective weight determination method. In information theory, the amount of information provided by data can be reflected through entropy. When the scheme data of an index differ greatly, the entropy is small and the amount of information provided is large, while when the data difference is small, the information provided is opposite (Shannon, 1948). The basic steps are as follows:

1. Determine the judgment matrix and standardize evaluation indexes

Assume there are *m* evaluation indexes and *n* evaluation objects, and then form the original data matrix $X = (x_{ij})_{m\times n}$. The matrix *F* can be obtained by standardizing the matrix.

$$F = (f_{ij})_{mxn} \quad (5)$$

$$f_{ij} = \begin{cases} \dfrac{x_{ij} - min_j x_{ij}}{max_j x_{ij} - min_j x_{ij}}, the\ efficiency\ index. \\ \dfrac{max_j x_{ij} - x_{ij}}{max_j x_{ij} - min_j x_{ij}}, the\ cost\ index. \end{cases} \quad (6)$$

Where, f_{ij} is the standard value of the *j* th evaluation object on the *i* th evaluation index, $f_{ij} \in [0, 1]$. Among them, the larger the benefit index is, the better, and the smaller the cost index is, the better.

2. Calculate the entropy and entropy weight of indexes

In the evaluation problem with *m* indexes and *n* evaluation objects, the entropy of the *i* th index is defined as

$$H_i = -k\sum_{j=1}^{n} b_{ij} ln\, b_{ij}, i = 1,2,\cdots,m \quad (7)$$

In order to prevent the occurrence of extreme values and simplify the calculation when the data is processed by standardized method, the translation value is set as 1. Where, k = 1 /ln*n*,$b_{ij} = (1 + f_{ij})/\sum_{j=1}^{n} b_{ij} = (1 + f_{ij})$. When $b_{ij} = 0$, $b_{ij}\ln b_{ij} = 0$. Thus, the entropy weight of the *i* th index can be defined as follows:

$$\omega_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \quad (8)$$

Where $0 \le \omega_i \le 1$, $\sum_{i=1}^{m}\omega_i = 1$.

Comprehensive weighting method to determine the weight of each index

The weights obtained by AHP and entropy weight method may be different when the same data are processed by different weights calculation methods, and the final optimal scheme may also be different. The subjective weighting method can reflect the decision maker's intention, but the evaluation result is subjective. However, the objective weighting method is highly theoretical, but it does not consider the intention of decision makers. Therefore, this study uses the subjective and objective comprehensive weighting method to determine the weight of each index.

Assuming that the index weight determined by AHP is ω_i^1 and that determined by entropy weight method isω_i^2, the comprehensive weight is ω_i as shown below

$$\omega_i = \omega_i^1\omega_i^2 / \sum_{i=1}^{m}\omega_i^1\omega_i^2 \quad (9)$$

VIKOR Method

The basic viewpoint of the VIKOR method is that the positive ideal solution and the negative ideal solution must be determined first. Then, the evaluation value of each alternative scheme is calculated, and the best scheme is selected according to its proximity to the ideal scheme (Tzeng and Huang, 2011). VIKOR algorithm is an aggregation function developed by L_{pj}-*metric*, as shown below:

$$L_P = \left\{\sum_{i=1}^{m}[\omega_i(f_i^* - f_{ij})/(f_i^* - f_i^-)]^P\right\}^{1/p} \quad (10)$$

Where, 1≤*p*≤∞, *p* is usually set as 1, measure L_p represents the distance from the evaluation index to the ideal solution, *i* is the evaluation index number, *i* = 1，2，…，*m*, *j* is the evaluation object number, *j* = 1，2，…，*n* and f_{ij} (standard value) represent the evaluation value of the *i* th evaluation index of the *j* th evaluation object, *m* is the number of evaluation indexes, *n* is the number of evaluation objects, ω_i is the weight of evaluation index, and f_i^* and f_i^-respectively represent positive ideal solution and negative ideal solution. The basic steps are as follows:

1. According to Equations (6) and (7), f_i^* and f_i^- can be obtained, which can also be divided into the efficiency index of the larger the better and the cost index of the smaller the better.

$$(f_i^*, f_i^-) = \begin{cases} (max_j f_{ij}, min_j f_{ij}), \forall\ i,, the efficiency\ index. \\ (min_j f_{ij}, max_j f_{ij}), \forall\ i, the\ costindex. \end{cases} \quad (11)$$

2. Calculate the maximum group benefit value S_j, minimum individual regret value R_j and benefit value Q_j of each evaluation object:

$$S_j = \sum_{i=1}^{m}\omega_i(f_i^* - f_{ij})/(f_i^* - f_i^-), \forall\ j \quad (12)$$

$$R_j = max_i\omega_i(f_i^* - f_{ij})/(f_i^* - f_i^-), \forall\ j \quad (13)$$

$$Q_j = \nu(S_j - S^*)/(S^- - S^*) + (1-\nu)(R_j - R^*)/(R^- - R^*), \forall\ j \quad (14)$$

Where, $S^* = \max S_j$, $S^- = \min S_j$, $R^* = \max R_j$, $R^- = \min R_j$, and *v*∈［0，1］ are the coefficients of decision-making mechanism. For equilibrium compromise, *v* =

Table 4. Air quality monitoring sample data

Monitoring point	Average daily concentration			
	TSP (mg/Nm³)	SO_2(mg/Nm³)	NO_X(mg/Nm³)	Noise dB(A)
1	0.8351	0.0430	0.0820	40.7
2	0.6824	0.1022	0.0674	46.0
3	0.5742	0.0264	0.0862	48.2
4	0.4728	0.0340	0.0778	42.1
5	0.6860	0.0534	0.0735	45.7

Table 5. Monitoring results of water quality samples

Monitoring point	Daily mean value		
	PH	COD (mg/L)	Suspended solids (mg/L)
1	7.41	27	30
2	7.45	30	29
3	7.66	22	25
4	7.68	23	23
5	7.61	21	24

Table 6. Social environmental impact factor evaluation results

Assessment indexes	Assessment results (0-100 points for each item from minimum to maximum)				
	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
X_4	80	85	80	90	85
X_5	60	65	55	60	55
X_6	90	80	85	90	75
X_7	50	55	45	45	50
X_8	60	70	80	70	65

Table 7. Evaluation results of ecological environment impact factors

Assessment indexes	Assessment results (0-100 points for each item from minimum to maximum)				
	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
X_9	80	65	75	85	70

(1: Wasteland-mildly fragile: 100-80 points; 2: Grassland-light fragile: 60-80 points; 3: Wetland-moderately fragile:40-60 points; 4: Woodland-fragile 20-40 points; 5: Cultivated land, extremely fragile: 0-20 points)

Table 8. Evaluation results of land resources impact factors

Assessment indexes	Assessment results (0-100 points for each item from minimum to maximum)				
	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
X_{10}	70	65	75	60	70

(1: the regional residents are satisfied, the government supports them, environmental and social benefits is obvious:100-80 points; 2: the regional residents are satisfied, the government supports them, better environmental and social benefits:60-80 points; 3: the government supports them, the government supports them, and relatively good environmental and social benefits: 40-60 points; 4: the regional residents are basically satisfied, moderate environmental and social benefits: 20-40 points; 5: the residents in the middle region do not recognize, the poor environmental and social benefits: 0-20 points)

0.5, in order to maximize group benefit and minimize individual regret.

3. Sort S_j, R_j and Q_j from small to large, and the smaller the number, the better. The optimal evaluation object corresponding to the minimum Q_j value shall meet the following conditions:

First, Acceptable benefit threshold conditions: $Q_j^2 - Q_j^1 \geq 1/(n-1)$, where Q_j^1 and Q_j^2 are the first and second evaluation objects; Second, Acceptable decision reliability: the $S_j$value (or R_j value) of the scheme with the highest Q_j value must also be higher than that of the scheme with the second highest ranking. If only the condition is satisfied, then the optimal scheme is Q_j^1 and Q_j^2; If only the condition is satisfied, then Q_j^1, Q_j^2, …, Q_j^M is optimal, and Q_j^M is the maximum M value determined by $Q_j^M - Q_j^1 < 1/(n-1)$.

CASE STUDY

Case Introduction

In order to verify the effectiveness of the above evaluation index system and evaluation model, we apply it to the environmental impact assessment of actual power plants. Take a coal-fired power plant in Taiwan (hereinafter referred to as T power plant) in operation as an example to evaluate its environmental impact. We set up 6 air completion points for the natural environment assessment index system, and the drainage water quality of power plants is tested twice a week for the export of industrial wastewater, domestic sewage and reclaimed water treatment units from January to March 2019. The mean value of the test was taken 5 times at different time points in February. Five academic experts in architecture, ecological conservation and sociology were asked to score the impacts of power plants in these two environments. The specific score is based on the following criteria: excellent (more than 90 points), excellent (80-90 points), average (70-80 points), fair (60-70 points), poor (0-60 points) (0-100 points for each item from minimum to maximum). The original data are shown in **Tables 4-8**.

Determine the Index Weight

According to the basic principle of analytic hierarchy process (AHP) and access to a large number of literature

Table 9. Preference matrix for the evaluation criteria (level 1 indices corresponding to level 1 indices)

Indices	Q_1	Q_2	Q_3	weight	C.R.
Q_1	1	2	3	0.5499	0.0184
Q_2	1/2	1	1	0.2402	
Q_3	1/3	1	1	0.2098	

Table 10. Preference matrix for the evaluation criteria (level 2 indices corresponding to level 2 indices)-1

Indices	X_1	X_2	X_3	weight	C.R.
X_1	1	3	3	0.5936	0.0542
X_2	1/3	1	2	0.2493	
X_3	1/3	1/2	1	0.1571	

Table 11. Preference matrix for the evaluation criteria (level 2 indices corresponding to level 2 indices)-2

Indices	X_4	X_5	X_6	X_7	X_8	weight	C.R.
X_4	1	1	1/2	1	1/3	0.1343	0.0820
X_5	1	1	1/2	1	2	0.1994	
X_6	2	2	1	1/2	1/2	0.1950	
X_7	1	1	2	1	2	0.2514	
X_8	3	1/2	2	1/2	1	0.2199	

Table 12. Preference matrix for the evaluation criteria (level 2 indices corresponding to level 2 indices)-3

Indices	X_9	X_{10}	weight	C.R.
X_9	1	2	0.6667	0.0001
X_{10}	1/2	1	0.3333	

Table 13. Preference matrix for the evaluation criteria (level 3 indices corresponding to level 3 indices)-1

Indices	X_{11}	X_{12}	X_{13}	weight	C.R.
X_{11}	1	1	2	0.3874	0.0174
X_{12}	1	1	3	0.4434	
X_{13}	1/2	1/3	1	0.1692	

Table 14. Preference matrix for the evaluation criteria (level 3 indices corresponding to level 3 indices)-2

Indices	X_{21}	X_{22}	X_{23}	weight	C.R.
X_{21}	1	1	3	0.4434	0.0190
X_{22}	1	1	2	0.3874	
X_{23}	1/3	1/2	1	0.1692	

Table 15. Total ranking of hierarchical indexes

Q													
Q_1 0.5499							Q_2 0.2402					Q_3 0.2098	
X_1 0.5936			X_2 0.2493			X_3 0.1571	X_4 0.1343₄	X_5 0.1994	X_6 0.1950	X_7 0.2514	X_8 0.2199	X_9 0.6667	X_{10} 0.3333
X_{11} 0.387	X_{12} 0.443	X_{13} 0.169	X_{21} 0.443	X_{22} 0.387	X_{23} 0.169	X_{31} 0.1571							
0.1263	0.1447	0.0552	0.0607	0.0531	0.0232	0.0864	0.0323	0.0479	0.0468	0.0604	0.0528	0.1399	0.0699

and consulting experts and scholars, preference matrix for the evaluation criteria (first level indices corresponding to first level indices, second level indices corresponding to second level indices, and third level indices corresponding to third level indices) are investigated. By calculating and checking the consistency, the weight of criterion layer and index layer can be obtained, as shown in **Tables 9**-**14**. According to the criterion layer corresponding to the target layer and the weight calculated by the criterion layer corresponding to the index layer, the weight W of the target layer corresponding to the index layer can be calculated, as shown in **Table 15**.

Results of AHP and Entropy Weight VIKOR Method

According to the proposed the AHP-entropy weight VIKOR method, the impact on the natural environment, social environment influence and quality assessment of ecological environmental are calculated as follows:

1. Calculate the entropy and entropy weight of each evaluation index according to Equations (5) to (8). Among them, sulfur dioxide emission concentration, nitrogen oxide emission concentration, TSP concentration, COD, suspended solids and noise decibels are all cost-type indicators. According to Taiwan drinking water standard PH value specification, the value is between [6.5, 8.5]. The remaining indicators, such as the impact on the surrounding social and economic development, the degree of contribution to technological progress, the impact of waste (comprehensive utilization rate of ash residue), the proportion of environmental investment, the impact on the surrounding residents, the impact of ecological environment and the impact on land resources, are all the efficiency indicators between [0,100]. We can calculate the entropy weight of each indicator is as follows:

W= (0.1535, 0.1234, 0.1816, 0.1834, 0.0029, 0.1508, 0.1939, 0.0005, 0.001, 0.0013, 0.0015, 0.0024, 0.0023, 0.0015)

Table 16. S, R, Q and proximity of 5 monitoring points

Monitoring point	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.6364	4	0.2436	5	0.9468	5	0.3989
2	0.6965	5	0.2244	4	0.9448	4	0.3348
3	0.4035	3	0.1399	2	0.4424	2	0.6081
4	0.1316	1	0.0697	1	0.0000	1	0.8369
5	0.3947	2	0.1433	3	0.4446	3 0.5832	

Table 17. S, R, Q and proximity of 5 monitoring points (Atmospheric environment)

Monitoring point	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.6577	5	0.4103	5	1.0000	5	0.3990
2	0.6149	4	0.3776	4	0.9016	4	0.3803
3	0.3270	2	0.2121	2	0.3327	2	0.6653
4	0.1552	1	0.1173	1	0.0000	1	0.8144
5	0.4448	3	0.2414	3	0.4999	3 0.5359	

Table 18. S, R, Q and proximity of 5 monitoring points (Water environment)

Monitoring point	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.7895	4	0.4210	4	0.7305	4	0.2766
2	0.9473	5	0.6315	5	1.0000	5	0.0674
3	0.1725	3	0.1013	2	0.1098	2	0.8332
4	0.1403	2	0.1403	3	0.1254	3	0.8119
5	0.0543	1	0.0507	1	0.0000	1 0.9326	

2. According to the analytic hierarchy process (AHP) and entropy weight method to calculate the weight of each index, according to the type (9), calculates the comprehensive weight is as follows:

W = (0.2436, 0.2244, 0.1260, 0.1399, 0.0019, 0.0440, 0.2105, 0.0002, 0.0006, 0.0008,0.00114, 0.0016, 0.0040, 0.0013)

According to the type (5), (6) and (10), (11) can be concluded that each index of the ideal solution and negative ideal solution are:

f_i^*= (0.2436, 0.2244, 0.1260, 0.1399, 0.0011, 0.0440, 0.2105, 0.0002, 0.0004, 0.0007, 0.0006, 0.0013, 0.0034, 0.0010),

f_i^-= (0, 0, 0, 0, 0.0009, 0, 0, 0.0002, 0.0003, 0.0006, 0.0005, 0.0010, 0.0026, 0.0008).

3. According to equations (12) - (14), S, R and Q values of the six atmospheric environment observation points were calculated and sorted, and the results were shown in **Table 16**. We can get the order of each monitoring point: point 4 > point 3 □ point 5 > point 1 □ point 2 >. At the same time, we calculated the proximity of 5 observation points by TOPSIS method, and found that the nearness of 1,2,3,4 and 5 TOPSIS points were between 0.3 and 0.8, indicating that the influence of 14 indicators of the 5 observation points was not consistent. Next, we further analyze the environmental impact of power plants within each level 1 indicator.

Atmospheric environmental impact analysis

It can be concluded that each index of the positive ideal solution and negative ideal solution are: f_i^* = (0.4103,0.3776, 0.2121), f_i^-= (0, 0, 0). S, R, Q and proximity of 5 monitoring points were shown in **Table 17**. We can get the order of each monitoring point: point 4 > point 3≃point 5 > point 1 ≃ point 2. **Table 17** showed that the proximity of monitoring points 4 and 3 was close to 06 - 0.8, indicating that the atmospheric environment influence control level was consistent and good. The proximity of monitoring points 2, 5 and 1 was far from that of monitoring points 4 and 3, which required more attention and subsequent influence control.

Water environmental impact analysis

It can be concluded that each index of the positive ideal solution and negative ideal solution are: f_i^* = (0.0082, 0.6315, 0.3547), f_i^-= (0.0063, 0, 0). S, R, Q and proximity of 5 monitoring points were shown in **Table 18**. We can get the order of each monitoring point: point 5 > point 3≃point 4 > point 1 > point 2. **Table 18** showed that the proximity of monitoring points 3, 4 and 5 was close to 0.8 - 0.9, indicating that the water environment influence control level was quite consistent and very good. The proximity of monitoring points 1 and 2 was far from that of monitoring points 3, 4 and 5, which required more attention and subsequent influence control.

Noise impact analysis

It can be concluded that each index of the positive ideal solution and negative ideal solution are: f_i^* = (1), f_i^-= (0). S, R, Q and proximity of 5 monitoring points were shown in **Table 19**. We can get the order of each monitoring point: point 1≃point 4 > point 2≃point 5 > point 3. **Table 19** showed that the proximity of monitoring points 1 and 4 was close to 0.8 - 1, indicating that the water environment influence control level was quite consistent and very good. And according to the noise control standards of Taiwan, the noise levels of all observation points were less than 50dB(A) and well controlled.

Table 19. S, R, Q and proximity of 5 monitoring points (Noise)

Monitoring point	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.0000	1	0.0000	1	0.0000	1	1.0000
2	0.7067	4	0.7067	4	0.7067	4	0.2933
3	1.0000	5	1.0000	5	1.0000	5	0.0000
4	0.1867	2	0.1867	2	0.1867	2	0.8133
5	0.6667	3	0.6667	3	0.6667	3 0.3333	

Table 20. S, R, Q and proximity of 5 monitoring points (Social environment)

Expert	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.6214	4	0.3676	5	0.8484	5	0.2855
2	0.3234	1	0.1838	1	0.0000	1	0.5435
3	0.5170	2	0.2655	3	0.4487	2	0.7033
4	0.5220	3	0.2655	3	0.4545	3	0.4996
5	0.7511	5	0.2757	4	0.7500	4 0.3675	

Table 21. S, R, Q and proximity of 5 monitoring points (Ecological environment)

Expert	S		R		Q		TOPSIS
	value	rank	value	rank	value	rank	proximity
1	0.2701	3	0.2419	3	1	3	0.7451
2	0.9195	1	0.0958	1	0	1	0.0728
3	0.3793	2	0.1396	2	0.5252	2	0.5256
4	0.2414	4	0.2419	4	1	4	0.8074
5	0.6494	5	0.0958	5	0	5 0.2821	

Social environmental impact analysis

It can be concluded that each index of the positive ideal solution and negative ideal solution are: f_i^*= (0.0436, 0.0945, 0.1558, 0.1460, 0.2941) , f_i^- = (0.0387, 0.0800, 0.1298, 0.1195, 0.2205). S, R, Q and proximity of 5 experts were shown in **Table 20**. The average score of the five experts on social environment items ranged from 65 to 85. **Table 20** showed that the proximity of experts 4 was close to 0.7, while other experts' proximity below 0.55, indicating that all experts believed that the impact of power plants on social environment could not be ignored.

Ecological environmental impact analysis

It can be concluded that each index of the positive ideal solution and negative ideal solution are: f_i^*= (0.6448,0.1810), f_i^- = (0.4931,0.1448). S, R, Q and proximity of 5 experts were shown in **Table 21**. The average score of the five experts on social environment items ranged from 60 to 75. **Table 21** showed that the proximity of experts 1 and 4 was close to 0.7-0.8, while other experts' proximity below 0.55, indicating that all experts believed that the impact of power plants on ecological environment could not be ignored.

CONCLUSIONS

In this paper, based on the characteristics of the coal-fired power plant, we considered the power plant operation on the influence of various aspects, the comprehensive natural environment, ecological environment and social economy, on the basis of three kinds of evaluation method, the influence of choosing AHP combined with entropy-based VIKOR method for environmental impact assessment, and coal-fired power plant environmental impact assessment model is established. Through comprehensive evaluation, it can verify whether each coal-fired power plant has a positive role in development. Taking Taiwan thermal power Plant as an example, this evaluation model evaluates the natural environment, social environment and ecological environment of the power plant based on the actual monitoring data in 2019. The evaluation results show that the air pollutants and waste water discharge of the power plant have room for improvement, the power plant has a certain impact on the surrounding ecological environment and social and economic environment, and the noise control is not bad.

Because of manpower, time and cost constraints, this study discusses the environmental impact factors in fire power plant selection only, not for other power generation type or different environmental factors affecting the selection of thermal power plant type further discussion, so suggest the follow-up for other power plant selection, such as hydraulic power plants, steam, wind farms, distributed power plants of symbiosis plant, etc. As for the hierarchical structure and establishment of weighting, this study mainly refer to the opinions of power plant planning experts, supplemented by engineering consultancy expert and executive power sector, but overall still is given priority to with engineering planning expert advice, not included in the energy sector, local government, the site of factory nearby residents and related disciplines, such as natural humanities, the social economy, etc.), expert opinion, the future advice can be to think from the perspective of different professional background or fire power plant environmental factors affecting the problem.

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